observations incidental to other work, and I only wish I knew where the special subject has been studied and described. The hydrothermal phenomena of the Devonian diabases, of the Devonshire quartz- and mica-schists, and of the green rocks, and of the so-called pegmatite felspathic veins connected with the green rocks—these present to my mind the most interesting problems in the debatable Devonshire area, and, compared with them, the question as to whether the schists are Archæan or Devonian, or, as has recently been suggested, any possible age between those geological horizons, does not matter the toss up of a bad halfpenny. Certainly, if neither Archæan nor Devonian I do not care what they are.

I may perhaps explain that I have never possessed a first-rate petrological microscope, and that for the work above referred to the small students' microscopes are about as useful as a pocket lens, as a mechanical stage and a somewhat elaborate achromatic condenser are as essential as are high-powered objectives. But the old microscopes with these fittings are lacking in other advantages. This fact, in addition to my not being well grounded in the identification of minerals, makes it impossible for me to attempt any difficult work myself, and that is really the reason why I have so often pressed these questions upon others, when every motive of self-interest would have bade me avoid unpopular doctrines and keep to the beaten track.

The motion of bubbles is the easiest proof of the presence of fluid. The following device, to induce a bubble to move, may not be known to all microscopists. If the substage condenser is furnished with a rotating diaphragm, to allow of oblique light from any point, such a diaphragm, if rotated under strong lamp light, will often make a bubble move owing to the heat thrown laterally upon the fluid inclusion.

Considering the attention paid to the subject of superheated water by Dr. Sorby and my eminent namesake, the late Dr. Sterry Hunt, more than a quarter of a century ago, it is most remarkable that the investigation has not been followed up with more vigour and determination by their successors. It is well worth conquering.

V.—The Pendleton Earth-shake of November 25th, 1905.

By Charles Davison, Sc.D., F.G.S.

PENDLETON lies on the north-west side of Manchester and within the borough of Salford, and is traversed by the well-known Pendleton or Irwell Valley fault, a fault which has been traced for more than twenty miles from the neighbourhood of Bolton to that of Poynton in Cheshire. The fault is still slowly growing, for, on February 10th, 1889, a slip near Bolton gave rise to an earthquake of intensity 6, felt over an area of about 2,500 square miles.[1] Small superficial movements may also be taking place close to

[1] Geol. Mag., Dec. III, Vol. VIII (1891), pp. 306–316.

Pendleton, though here probably aided by mining operations. Within the last seven years there have been local shakes on three occasions, namely, February 27th, 1899, April 7th, 1900, and November 25th, 1905. The materials for the study of the first two of these shakes are not quite sufficient to determine the boundaries of their disturbed areas with accuracy. The areas appear, however, to have been approximately circular in form and about four or five miles in diameter. In both cases the intensity of the shock was 4, or nearly 5. In 1899 the centre of the disturbed area was about half a mile north of Pendleton and a short distance on the north-east or downthrow side of the Pendleton fault; in 1900 it lay a mile or two farther to the south or south-south-east of the former centre.[1]

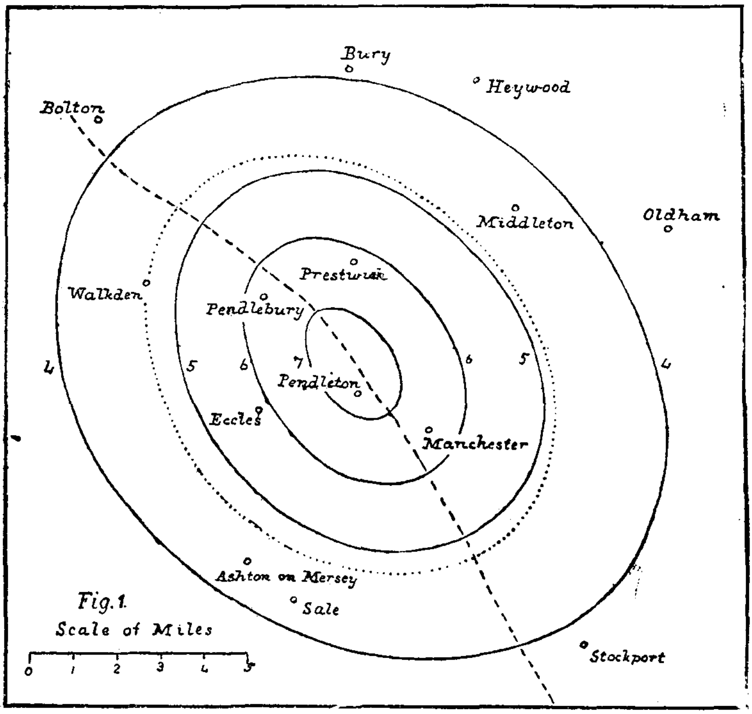

FIG. 1.—Isoseismal lines of Pendleton Earth-shake, Nov. 25th, 1905.

The earth-shake of November 25th, 1905, was strong enough to be noticed in many besides local newspapers, and was investigated without delay. The materials for its study are therefore abundant, the following account being based on 139 records from 45 places, and on negative records from 4 places.

[1] GEOL. MAG., Dec. IV, Vol. VII (1900), p. 175; Dec. IV, Vol. VIII (1901), p. 361.

The shock occurred at 3.42 a.m., the centre of the disturbed area being $\frac{3}{4}$ mile north of the centre of Pendleton (in lat. 53° 29·6′ N., long. 2° 15·8′ W.). At this place the intensity of the shock was 7, and not much below 8, for there was some slight damage done, several chimney-pots and one chimney-stack being thrown down. On the accompanying map (Fig. 1, which is bounded by the parallels of 53° 37′ and 53° 23′ N. lat. and by the meridians of 2° 4′ and 2° 29′ W. long.) four isoseismals are shown, corresponding to intensities 7 to 4. The isoseismal 7 is 3 miles long, $1\frac{3}{4}$ miles wide, and 4 square miles in area, but, towards the east, the curve may not be quite accurately drawn. The next isoseismal, of intensity 6, is 6 miles long, $4\frac{1}{2}$ miles wide, and contains 21 square miles; the isoseismal 5 is $9\frac{1}{2}$ miles long, $7\frac{1}{2}$ miles wide, and 56 square miles in area; while the isoseismal 4, which bounds the disturbed area, is $15\frac{1}{4}$ miles long, 12 miles wide, and includes an area of 144 square miles. The longer axes of the isoseismal lines are parallel or nearly so, and run from N. 37° W. to S. 37° E. The distances between the isoseismals are approximately the same on both sides of the longer axes.

The shock was brief in all parts of the disturbed area, the average of 11 estimates of the duration being $2\frac{1}{2}$ seconds. It consisted of a few prominent vibrations, quick-period tremors having been apparently absent.

The sound-area, which is bounded by the dotted line on the map, is $10\frac{3}{4}$ miles long, $8\frac{1}{4}$ miles wide, and contains 70 square miles. It includes the whole of the isoseismal 5, but falls short of the isoseismal 4 in all directions. The sound was heard by 75 per cent. of the observers. By 14 per cent. of these it was compared to passing traction engines, etc., by 13 per cent. to thunder, by 4 to wind, 9 to loads of stones falling, 31 to the fall of a heavy body, and by 29 per cent. to explosions; that is, 31 per cent. of the observers refer to types of long, and 69 to types of short, duration. The beginning of the sound preceded that of the shock in 49 per cent. of the records, coincided with it in 24, and followed it in 27, per cent.; while the end of the sound preceded that of the shock in 13 per cent. of the records, coincided with it in 16, and followed it in 71, per cent. The duration of the sound was greater than that of the shock in 87, and equal to it in 13, per cent. of the records.

In the rapid decline of intensity outwards from the epicentre, and in the nature of the sound-phenomena, the Pendleton earth-shake differs widely from other shocks in Great Britain.

(i) Decline of Intensity.—During the last seventeen years there have been eight British earthquakes of intensity 7 (and nearly 8), namely, the Inverness earthquakes of 1890 and 1901, the Pembroke earthquakes of 1892 and 1893, the Derby earthquakes of 1903 and 1904, the Carnarvon earthquake of 1903, and the Doncaster earthquake of 1905. In the following Table, the average areas contained by the different isoseismals are contrasted with the corresponding figures for the Pendleton earth-shake :—

Isoseismal.	Area in Square Miles.	
	Average of the above earthquakes.	Pendleton earth-shake.
7	500	4
6	2,500	21
5	8,300	56
4	22,000	144

(ii) Sound-Phenomena.—In earthquakes which disturb an area of not more than a few hundred square miles the average percentage of audibility is about 98, and the sound-area coincides with, or overlaps, the disturbed area. Thus, in its audibility and contracted sound-area, the Pendleton earth-shake differs from other shocks with a small disturbed area. Nor does it differ less in the nature of the sound, as will be seen from the next Table, in which the figures represent percentages of the total number of comparisons to the different types mentioned, for slight British earthquakes, the Pendleton earth-shake, and similar earth-shakes of small and approximately circular disturbed areas.

Sound-type.	Slight Earthquakes.	Pendleton Earth-shake.	Small Earth-shakes.
Passing waggons, etc.	31	14	...
Thunder	35	13	6
Wind	3	4	...
Loads of stones falling	8	9	12
Fall of heavy body ...	6	31	35
Explosions	14	29	47
Miscellaneous ...	4	...	...

The Pendleton earth-shake bears, indeed, a closer resemblance to the earthquakes which are characteristic of volcanic regions. For the sake of comparison, I reproduce in Fig. 2 the map of the isoseismal lines of the Etnean earthquake of August 8, 1894,[1] on half the scale of the map of the Pendleton shake. The curve marked A bounds the ruinous zone, in which buildings were destroyed and several persons killed. The curve B bounds the "very strong" zone, in which slight damage to buildings occurred; the curve C the "strong" zone, in which the shock was strong enough to make lamps, etc., swing; while, in the "slight" zone indicated by the curve D, the shock was just strong enough to be sensible.

In both cases it is clear, from the rapid decline in intensity, that the focus was situated at a very small depth. Secondly, in the Pendleton earth-shake, it follows, from the nature of the sound, that the focus was of larger dimensions than in the weak earth-shakes,

[1] M. Baratta, "Intorno ai recenti fenomeni endogeni avvenuti nella regione Etnea": Boll. della Soc. Geogr. Ital., Oct. 1894.

but smaller than in that of the slight, but true, earthquakes. Judging from the lengths of the axes of the inner isoseismal, it can hardly have been less than one mile, and may have been as much as one and a half miles, in length.

If the earth-shake were due to fault-slipping, the direction of the originating fault must be parallel or nearly so to that of the longer axes of the isoseismal lines, or about N. 37° W. to S. 37° E.; its hade being indeterminate, since each pair of isoseismal lines is separated by the same distance on both sides of the longer axes.[1]

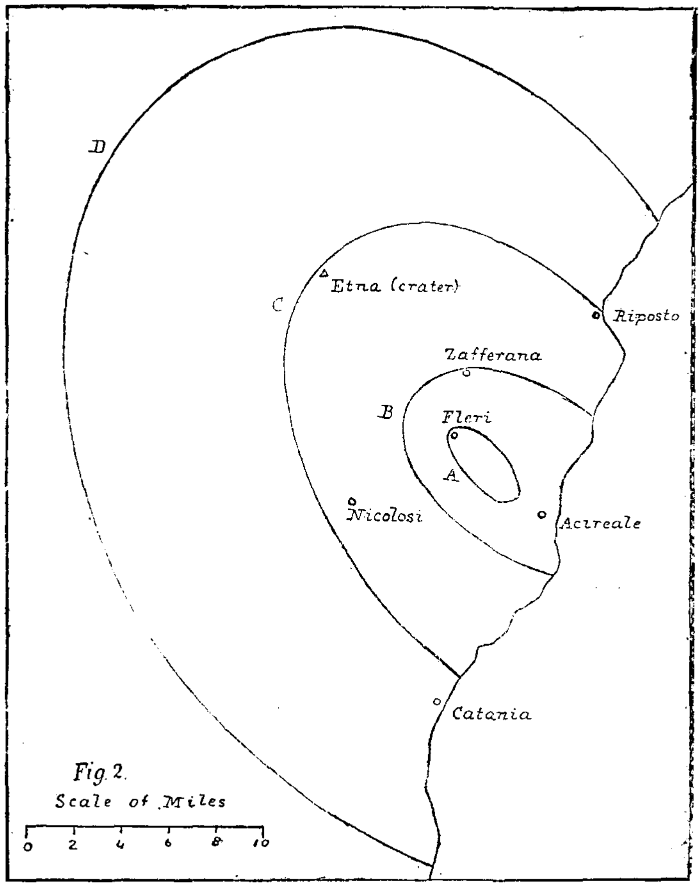

FIG. 2.—Isoseismal lines of Etnean Earthquake, Aug. 8th, 1894.

Now, in the neighbourhood of Pendleton, the mean direction of the Pendleton fault is from N. 34° W. to S. 34° E., and from its position, as indicated by the broken line on the map, we may,

[1] This would be the case if the vertical dimension of the focus was small.

I think, conclude that the earth-shake was due probably to a slip of this fault, but possibly to a subsidence along a band determined by, and closely adjoining, the fault. What the depth of the focus was we have no means of determining exactly, but it can hardly have been greater, and was probably much less, than a quarter of a mile, that is, considerably less than the depth of the present workings, which are from 800 to 1,100 yards below the surface.

That the shock was primarily due to work in connection with the mines there can, I think, be little doubt. The slip, whether along the fault or otherwise, can hardly have been precipitated directly by the withdrawal of the coal, but rather, as suggested to me by Mr. Joseph Dickinson, by the pumping of water in the overlying beds.[1] On this supposition, the slight depth of the focus, its great horizontal and small vertical dimensions, and the long interval that has elapsed since the working of the coal near the fault, would all receive a satisfactory explanation.

VI.—A Cordierite-bearing Lava from the Lake District.

By Alfred Harker, M.A., F.R.S.

ALTHOUGH the volcanic rocks of the English Lake District have received notice from time to time, any systematic account of them from the petrographical side has yet to be written. The most recent contribution, by the late Mr. E. E. Walker,[2] treated especially of the mode of occurrence of the garnet, which is so common a constituent, not only of the lavas and tuffs, but of the associated intrusive rocks, probably referable to the same Ordovician age. There can be no doubt that this mineral is sometimes a primary constituent, but very often a product of metamorphism. The object of the present note is to record the occurrence in one instance of a rarer mineral, which has not hitherto been observed in this series of rocks. Cordierite is found as a product of thermal metamorphism in the Coniston Flags near the Shap Granite,[3] and in the Skiddaw Slates of the Skiddaw granite area.[4] In the latter it is remarkably abundant and wide-spread.[5] The mineral is now found to occur, as an exceptional constituent, in the volcanic series.

The specimen was collected sixteen years ago on Sty Head Pass, just south of the watershed. As it does not, to the eye, present any unusual appearance, its occurrence was not more particularly noted. It comes then in the midst of the volcanic succession, between the principal group of basic lavas and the thick breccias and tuffs which build the central mountains of the district. Dr. Marr[6] has expressed the opinion that a large part of the garnetiferous rocks which occur

[1] For a similar suggestion see Geol. Mag., Dec. V, Vol. II (1905), p. 223.
[2] Quart. Journ. Geol. Soc., vol. lx (1904), pp. 70–104.
[3] Hutchings, Geol. Mag., 1894, pp. 65, 66.
[4] Harker, ibid., pp. 169, 170.
[5] Harker, *Naturalist*, 1906.
[6] Proc. Geol. Assoc., vol. xvi (1900), pp. 476, 477, and map, pl. xiii.